

Oort's 1965 review of stellar dynamics

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ORIGINAL and productive scientists often fight shy of writing review articles. One therefore sees an interesting and different facet of Oort's scientific personality revealed in the review article on stellar dynamics which he contributed to the famous *Stars and Stellar Systems* series initiated by Kuiper and Middlehurst and published by the University of Chicago Press. Volume V of this series was edited by Blaauw and Schmidt and devoted to Galactic structure. Given that the subject of stellar dynamics had already been covered in treatises by the likes of Eddington, Jeans, and Chandrasekhar, it is natural to ask what was Oort's special touch in these fortysix pages (plus an appendix) which have rightly been required reading ever since for entrants to the subject. The first characteristic is that material not directly connected with observations of our Galaxy or their interpretation is uncompromisingly omitted. Equally ruthlessly, all mathematical derivations are left out, giving reference to where they may be found. In lesser hands, this approach would have produced a fragmented and unreadable compendium. It does not, in this article, for two reasons. For one thing, physical principles and interpretation of the equations are given a full and clear discussion. Secondly, the ordering of the material is very logical—random motions, vertical motions, circular motion, small and then large deviations from circular motion. The primary requisites of a review article, readability and comprehensibility, are present in full measure.

Coming to individual sections, the one on motion perpendicular to the galactic plane represents the author's own special interests and contributions. The basic method, due to Oort himself, of determining the mass density from the vertical distribution and velocities of a group of stars (K. giants) is straight-

forward at least with hindsight. What is special is the insistence on precise numbers and the careful comparison of the dynamical estimate with known forms of matter—stellar and gaseous. Even when direct observations were not available at that time, as in the case of molecular hydrogen, ingenious astrophysical arguments are advanced to constrain the density. The final conclusion, that about half the mass density in the midplane of the Galaxy is in some unknown form, has not really been disproved by later work, and continues to intrigue astronomers even at present when the empirical data and computational power have multiplied manifold. This is one factor of two which is vital to astrophysics! One may remark in passing that in discussing the physical basis of the study of vertical motions, Oort relies more on the properties of individual orbits rather than on constants of motion (i.e., Jeans theorem). This passage has the basic idea of Schwarzschild's computational approach to galaxy dynamics which proved so useful more than a decade later.

The section on small deviations from circular motion is of course based on Oort's early work on galactic differential rotation, a topic covered in more detail in Chanda Jog's article in this issue. Again, Oort's attention goes unerringly to the empirical fact which may be telling us something new—the so-called 'vertex deviation'. The principal axes of the distribution of random velocities deviate from what the simplest model would predict, viz. parallel and perpendicular to the direction of the galactic centre. Non-circular motions due to spiral structure are brought in as a possible cause. Another interesting observed effect which is discussed is 'asymmetric drift'. This asymmetry between the numbers of stars moving faster and slower than the

sun translates into information on their radial distribution in the galaxy.

Large deviations from circular motion mean that we can observe, near the sun, starry messengers from the outer and inner galaxy. These motions must also reflect some properties of the early collapse phase of the galaxy—a theme which of course underlies the celebrated work of Eggen, Lynden-Bell, and Sandage and its later successors.

Having mentioned Oort's avoidance of theory for its own sake, it is remarkable to note that the seeds of the currently very fashionable field of Hamiltonian chaos were put down in early studies of large amplitude motions perpendicular to the galactic plane. The appendix to Oort's article by his colleague Ollongren represents one of the earliest of such studies, lesser known (and possibly less comprehensive) than the work of Henon and Heiles somewhat later which is rightly viewed as a landmark. Oort's motivation came, of course, from high velocity stars. It is again worth noting that Oort was ready to harness computer power to reach astronomical goals at a time when many others suffered from ideological inhibitions which have not entirely disappeared even today.

It is worth quoting from the remarks with which the

article concludes '... requirements that should ultimately be satisfied by a model of the galaxy is that not only should there be consistency between velocity and density distributions for each of the populations but that (they should imply a) field of force fitting the rotation curve'. The spirit of doing justice both to dynamical principles and to all the observations when one builds models could scarcely be expressed more concisely or forcefully.

It would be a daunting task indeed to review stellar dynamics about a decade later in the same series of volumes. Yet advances in observation, especially of external galaxies, and in theory and computation made this necessary and the result was Freeman's article 'Stellar dynamics and the structure of galaxies' in Volume IX, edited by Sandage, Sandage and Kristian. This excellent successor to Oort's article is worth mentioning, especially valuable to students and others entering this field of astronomy. More than a decade later, the subject finally found its *magnum opus* with the publication of 'Galactic dynamics' by Binney and Tremaine (Princeton 1987). Much water has indeed flowed under the bridge since 1964, but it is remarkable how much can still be learnt from Oort's fortysix pages.